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COMBINING MONOLITHIC AND REPACKED SOIL TANKS FOR HIGH WATER TABLE LYSIMETERS

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Summary:
Soil monoliths collected above a water table and soil tanks repacked with soil from below the water table were combined for weighing lysimeters to be used in soil salinity research. Innovative equipment and procedures were used to collect the monoliths which were then transported 80 km to a research location, joined with the repacked soil tanks and placed within weighing lysimeters.

Keywords:
Monolith, Lysimeter, Repacked, Salinity, High Water Table

COMBINING MONOLITHIC AND REPACKED SOIL TANKS FOR HIGH WATER TABLE LYSIMETERS[1]

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ABSTRACT

Soil monoliths collected above the water table and soil tanks repacked with soil from below the water table were combined for weighing lysimeters to be used in soil salinity research. Deadweights were used to press two, 2 x 4-m surface area by 1.68-m deep tanks into the soil, and the enclosed monoliths were undercut with steel plates. Innovative new equipment was used to control the deadweight movement, to maintain straight walls on the monolith tanks and to place the undercutting plates beneath the soil tanks. The monoliths and the soil for repacking the 1.07-m deep lower tanks were trucked 80 km to a research location where the monolithic and repacked soil tanks were joined and placed on weighing lysimeters. The monolithic/repacked soil tanks are expected to provide the advantages of a monolithic lysimeter without the disadvantage of lowering the high water table for collection of a deep monolith.

INTRODUCTION

The irrigated lands along the west side of the San Joaquin Valley are subject to high water tables and severe salinity problems (San Joaquin Valley Drainage Program, 1990). The USDA Agricultural Research Service (ARS) in cooperation with California State Agencies is conducting research to develop management guidelines for these difficult to manage soils. The goals of this cooperative research are to measure soil water hydraulic parameters, calibrate crop water use and salt transport models and evaluate irrigation management scenarios. Weighing lysimeters are the primary research tool to be used in collecting data for the model calibrations and evaluation of the irrigation scenarios.

Obtaining reliable data within a short time span placed restrictions on the soil tanks to be used with the lysimeters (Schneider and Howell, 1991). Monolithic soil tanks were required to preserve the soil hydraulic properties and the developed salinity profile (Marek et al., 1988). The soil tanks needed to be deep enough to allow the water table to range between the 1.0 and 2.5 m depths. Soil tank area needed to be sufficiently large to allow both accurate evapotranspiration

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and crop yield measurements. Collection of a deep soil monolith was complicated by the high water table that is seldom deeper than 1.75 m. Finally, the high water table areas are remote from any ARS locations, and the research would best be conducted at a laboratory with easy access to and control of the lysimeters.

In this paper, we describe the equipment and procedures for collecting upper monolithic soil tanks, repacking lower soil tanks and joining the two tanks into a single soil tank for the weighing lysimeters.

EQUIPMENT DESIGN

To meet the unique research requirements we designed two, combined, monolithic/repacked soil tanks and located the lysimeters approximately 80 km from the high water table site. The monolith collection site located 13 km south of Mendota, CA and 3 km east of State Highway 33 is near the natural drainage way of the South San Joaquin Valley. The soil is a uniform clay with high salt content, but it has not been classified. After the monoliths were collected they were trucked to the lysimeter site at the ARS research location at Parlier CA. We then excavated saturated soil from beneath the monolith collection site to fill repacked soil tanks with the same surface area as the monolithic tanks. The upper monolithic and lower repacked soil tanks were joined together, and the combined tanks were placed on the weighing lysimeter scales. All equipment was specifically designed to minimize hand labor by utilizing large equipment and power tools. Since the lysimeters are not located at the monolith collection site, we did not need to be concerned about soil compaction or other site disturbances.

The traditional monolith collection process of pressing down a bottomless steel tank and then undercutting the enclosed monolith was utilized. The steel monolith tanks had features for preventing warping of the walls and for providing safe, controlled downward movement. Force for pressing down the steel tanks was accomplished with deadweights because the saturated soil did not have sufficient strength to support high capacity anchors. The enclosed monoliths were undercut with solid steel plates so that the bottom of the monoliths were totally enclosed during hauling. The lower tanks were repacked by packing the desired weight of soil in 0.15-m depth increments and then saturating and draining the repacked soil.

For strength during the monolith collection process and thin walls in the completed lysimeter, we selected steel soil tanks. The soil tanks and specialized equipment for collecting the soil monoliths were designed and fabricated by ARS personnel. Unless otherwise noted, all steel in the tanks and monolith collection equipment is ASTM A36 structural steel.

Soil Tanks:

Both the monolithic and repacked soil tanks had 9.5-mm thick steel walls, had a 2-m by 4-m surface area and were reinforced with 100 x 50 x 6.4-mm rectangular tubing. The bottom edges of the 1.68-m deep monolithic tanks were beveled 45° to the inside to form a cutting edge. The 1.07-m deep lower tanks, constructed similar to the upper tanks, had two rings of reinforcing tubing and 15.9-mm thick bottoms.

The monolithic soil tanks had several additional features to facilitate collecting and lifting the monoliths, Figure 1. Two lifting eyes were attached to each 4-m long wall of the tanks to facilitate handling the monoliths and later lifting the combined tanks onto the lysimeter scales. The walls were reinforced at the bottom with heavy steel angles to reduce warping. These reinforcing angles extended beyond each end of the tanks so that lowering hoists could be easily attached to the tanks. Weight transfer columns with 22.2-mm adjusting bolts on top were placed around the monolith tanks. With these columns, deadweight was transferred directly through the transfer columns and reinforcing angles to the cutting edges. The transferred weight placed a moment on the reinforcing angles and rotated the bottom of walls inward. These actions largely eliminated the forces tending to deform the monolith tank and bulge the walls outward.

Deadweights:

For deadweights we used the heavy steel plates to be used to undercut the monoliths and the lower soil tanks filled with water. The four steel undercutting plates were 19.1 mm thick and each weighed 0.780 Mg. The two lower soil tanks each weighed 2.13 Mg and could be filled with an additional 8.53 Mg of water. Total deadweight available with this equipment was 24.44 Mg.

Lowering Equipment:

To provide alignment of the monolith tanks and vertical control of the deadweights we utilized lowering equipment at each end of the monolith tanks, Figure 2. Steel frames with a 10-Mg capacity were set in concrete anchors located deep enough to not interfere with lowering the monoliths. Four chain hoists each with a 4.5-Mg capacity were suspended from shackles in the frames and were attached to the heavy angles extending from the monolith tanks. With this design, the four hoists could be released simultaneously to provide safe, controlled downward movement of the monolith tanks and deadweights.

Undercutting equipment:

The three main components of the monolith undercutting equipment were the undercutting plates, the jacking equipment and the guide frames, Figure 3. Half of a monolith was undercut from each end to halve the maximum force for pulling the undercutting plates. The undercutting plates were mild steel 2.44 x 2.13 m by 19.1 mm thick. The leading edge was beveled at a 45°angle to the top, and a 3 x 25 mm bar was welded along the lower edge to reduce friction on the sliding plate. The guide frame was fabricated of 100 x 100 x 12.7 mm angle and suspended from the monolith tank with chains and 19-mm turnbuckles.

The jacking equipment consisted of two, single-acting, hollow-cylinder hydraulic jacks, telescoping bars on each side of the monolith tank, and a jacking beam opposite the undercutting plate, Figure 3. Simplex Model RC306[3] hydraulic jacks with a 269 kN capacity were powered by an Enerpac Model PEM 2022 electric powered hydraulic pump. The pump operated on 120 VAC and provided 690 mL/min of hydraulic oil at a maximum pressure of 69 MPa. The telescoping, 100 x 25 mm steel bar on each side of the monolith tank pinned into two short bars welded to the undercutting plates. Holes for a 25-mm pin were drilled every 125 mm along one end of the telescoping bars. Threaded 25-mm rods of AISI 4140 steel were welded to the other end of the bars and passed through the jacking beam and hollow cylinders of the jacks. The jacking beam was a 200-mm deep, wide-flange I-beam with the web reinforced on each end to resist the large shear force. On each end of the beam, heavy wall steel tubing was welded to the beam web and reinforcing to supporting the hollow cylinder hydraulic jack.

PROCEDURE

Monolith Collection:

Site Preparation: Site preparation consisted of installing the lowering frames and positioning the monolith tanks, hoists and deadweights. To install the lowering frames we excavated a 0.6-m wide trench with a backhoe, suspended the lowering frames at the correct elevation and placed high-early-strength concrete around the bottom of the frames. The monolith tanks and dead weights were lifted and placed with a 30-Mg capacity hydraulic crane. Figure 4 illustrates a tank and equipment in place and ready to begin the pressdown operation.

Pressing Down Monolith Tanks: Pressing down a monolith tank was a repeated sequence of lowering a tank and then excavating around the tank. We lowered a tank with the chain hoists until the reinforcing angles rested on the soil surface. Then, we excavated along the 4-m long walls to about 0.3 m below the cutting edge with a backhoe. Initially, the soil trimmed by the 2-m long walls of the tank fell into the trenches for the lowering frames, but as the tank was pressed deeper, this soil had to be shoveled into the backhoe trench. We were careful to leave about 150 mm of undisturbed soil between the tank wall and the trench. Having undisturbed soil on both sides of the cutting edge reduced the tendency of

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[3] Mention of a trade name or product does not constitute a recommendation or endorsement for use by the U.S. Department of Agriculture, nor does it imply registration under FIFRA as amended.

the walls to bulge outward. Both monolith tanks were lowered about 1 m with the 7.38-Mg deadweight of the undercutting plates and lower soil tanks. We then filled the lower of the two soil tanks with water, and were able to press down both monolith tanks with 15.9 Mg of weight or less. By putting excess weight on the monolith tanks and then lowering the tanks with the chain hoists we maintained complete control of the lowering rate at all times. Releasing the ratchet type chain hoists uniformly, allowed us to continuously maintain the tanks in a level position using carpenters levels. With this control there was no danger of the water shifting in the tanks. With five workers we could easily press down a monolith in one 6-h working day. The most difficult task was trimming soil from the monolith tank walls before the soil compacted against the reinforcing angles.

The loading on the weight transfer columns was continuously increased as the monolith tanks were pressed down. Initially, a small fraction of the load was lifted with the adjusting bolts at the top of the weight transfer columns. As the pressdown depth increased, we increased the force on the columns until the columns supported essentially all of the dead weight. As water was added to the tanks, the adjusting bolts were further extended to compensate for any bending in the reinforcing angles and the plates directly above the monolith tank.

Undercutting Monoliths: Before positioning the undercutting equipment, several items had to be removed from the soil tanks. The water in the lower tank was drained back into a water trailer, the weights and lowering frames were removed with the crane, the transfer columns were removed from the monolith tank, and the reinforcing angle extensions and gussets were cut off with an acetylene torch. Then, we excavated at both ends of a monolith tank to provide room for the undercutting plates.

Positioning of the undercutting equipment began with the guide frame which was bolted together beneath the monolith tank and supported with the turnbuckles, Figure 3. Then, an undercutting plate was positioned with the cutting edge on the guide frame and the opposite edge supported by a 10-Mg hydraulic jack. The front edge of the undercutting plate was pulled snugly against the bottom of the monolith tank with the turnbuckles. The guide frame thus insured that plate would cut directly beneath the tank. The jacking beam, telescoping linkage and hydraulic jacks were then positioned, and the hoses form the hydraulic pump were attached to the jacks.

The undercutting procedure was a repetition of advancing the plate about 150-mm with the hydraulic jacks and then repositioning the telescoping bar for the next cut, Figure 5. Individual valves on the hydraulic lines allowed us to control the rate of either jack and thus keep the plates aligned with the tanks. The jacks did not have spring retracting cylinders so we used 1-Mg hoists to collapse the jacks and position the telescoping bars for repinning. Jacking one of the undercutting plates under half of the monolith tank took a crew of 5 workers about

1 h. After jacking the first plate, we reversed the jacking equipment and jacked in the second plate from the opposite side.

Transporting Monoliths:

After the monoliths were undercut, we loaded them on trucks and hauled them to the ARS research location at Parlier, CA. Lifting was with a 91-Mg capacity crane, Figure 6, and hauling was with drop-bed tractor trailers having eight load wheels on both the tractor and trailer. For the first monolith loaded, we attached each undercutting plate to the monolith tank with four 8-mm link chains tensioned with load binders. This monolith slipped down inside the tank about 25 mm, but the second monolith with six chains on each plate had essentially no slippage. The load indicator in the crane indicated weights of 25.4 and 25.9 Mg for the two monoliths as shown in Figure 6. At Parlier, the monoliths and bottom tanks were positioned so that they could be readily joined after repacking the lower tanks with soil.

Repacking Lower Tanks:

Soil was excavated at the monolith collection site, hauled to Parlier and stored under plastic tarpaulins while the bottom tanks were being prepared for instrumentation. The tarpaulins prevented leaching of salts by rainfall during the winter months. Prior to packing the tanks, the soil water content was gravimetrically measured for each soil pile. The weight of soil required for 0.15-m depth increments was calculated based on the gravimetric water content and the desired bulk density. The inside of the tank was then marked in 0.15-m depth increments. The two lower 0.15-m depth increments were filled with washed sand to cover drainage and subsurface irrigation tubes. Then, soil was shoveled into a 113-L metal trash can, weighed and lifted into the soil tank with a backhoe. A running total was kept of the weight of soil added to each increment. The soil was spread with a rake and tamped with a 30-cm^2 tamper as needed to place the required weight of soil within the 0.15-m increments. Three workers working 5 to 6 h a day were able to repack one lower tank in 5 d.

Joining Soil Tanks:

The soil tanks were combined by carefully positioning the monolithic tank over the repacked tank with a 91-Mg capacity crane, Figure 7, and then joining the two tanks by welding. Accurately positioning a heavy load with a crane is difficult, so we built alignment frames to align the upper and lower tanks. Each undercutting plates was attached to the monolith tank with seven 8-mm chains, the monolith was lifted and positioned over the lower tank and the alignment frames were connected to both tanks. When the tanks were satisfactorily aligned, we lowered the monolith tank onto the lower tank.

Removal of the undercutting plates proved to be the most difficult part of the tank joining operation. To simultaneously pull out the two plates from under a monolith, we rented two heavy-duty towing trucks with each having a single-line winch capacity of 133 kN or greater. With double lines the winches had sufficient pulling capacity to pull the undercutting plates, but the towing trucks did not have sufficient traction. For each pair of undercutting plates, the winch trucks had to be assisted with two, 10-Mg, hand, hydraulic jacks placed between the plates. The plates had to be jacked about half of the 2-m distance before the towing trucks had sufficient traction to pull them.

After the plates were removed, the monolith tanks settled onto the lower tanks and only minor horizontal alignment was needed. This alignment was done by welding a jacking jig to the inner wall and pulling the inner wall even with the outer wall before welding. Because of minor bulges in the walls of the upper tank, the lower wall was generally the wall needing to be pulled out.

DISCUSSION

The combined monolithic/repacked soil tanks were satisfactorily completed and several aspects of the procedure were innovative or unique.

1. In collecting the monoliths, the use of the lowering frames allowed precise control of the weighted down tanks and safe use of water tanks as dead weights.

2. The weight transfer columns and reinforcing beams allowed us to maintain a straight 4-m long wall as the monolith tanks were pressed down.

3. The electric powered hydraulic jacks allowed us to undercut the monoliths in a few hours; whereas, other researchers have timed this operation in days or weeks.

4. To our knowledge, these are the largest reported soil monoliths transported a long distance for placement in a lysimeter.

5. Finally, collecting the monoliths, repacking the lower tanks, and joining the tanks were all accomplished in a timely manner and without large amounts of hand labor.

Our decision to use heavy machinery and power equipment whenever possible resulted in timely collection of the monoliths, repacking of the lower soil tanks and joining of the tanks. After the lowering frames were installed, we pressed down and undercut the monoliths with five workers and a crane/backhoe operator in 5.5 days. Because of differences in work schedules between the USDA employees and the crane/backhoe operator our working days were normally 6 h or less. Loading, hauling and unloading the two monoliths required 1.5 d because the crane service was late in arriving at the job site the first day. Positioning the two soil tanks for welding required three workers plus the crane and two winch truck operators about 7 h but most of this time was required to hand jack the undercutting plates.

Our experience suggests only limited modifications in the equipment or procedures we used. Pressing down and undercutting the monoliths was accomplished rather easily and we propose no major modifications. Some of our equipment such as the jacking beam and telescoping bar were too heavy to be easily handled by workers in the pits around the monoliths. Designing these lighter or in readily bolted together sections would be an improvement. Joining of the two tanks could have been made much easier if we had placed struts such as 150 or 200-mm standard pipe between the winch trucks and the soil tanks. The struts would have prevented the winch trucks from skidding and eliminated several hours of hand jacking to remove the undercutting plats.

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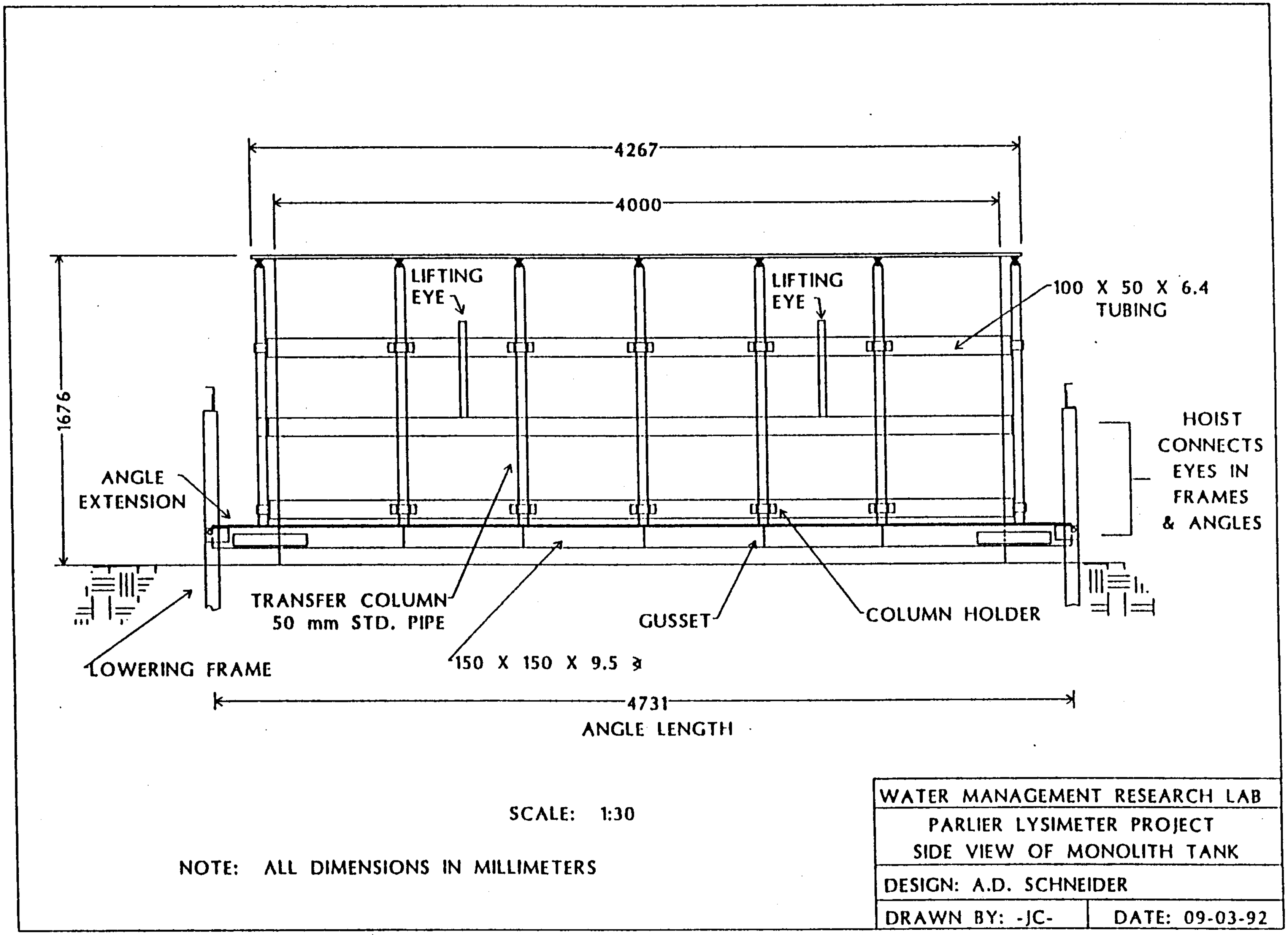

Figure 1. Side view of a monolith tank with temporary attachments and the upper section of the lowering frames.

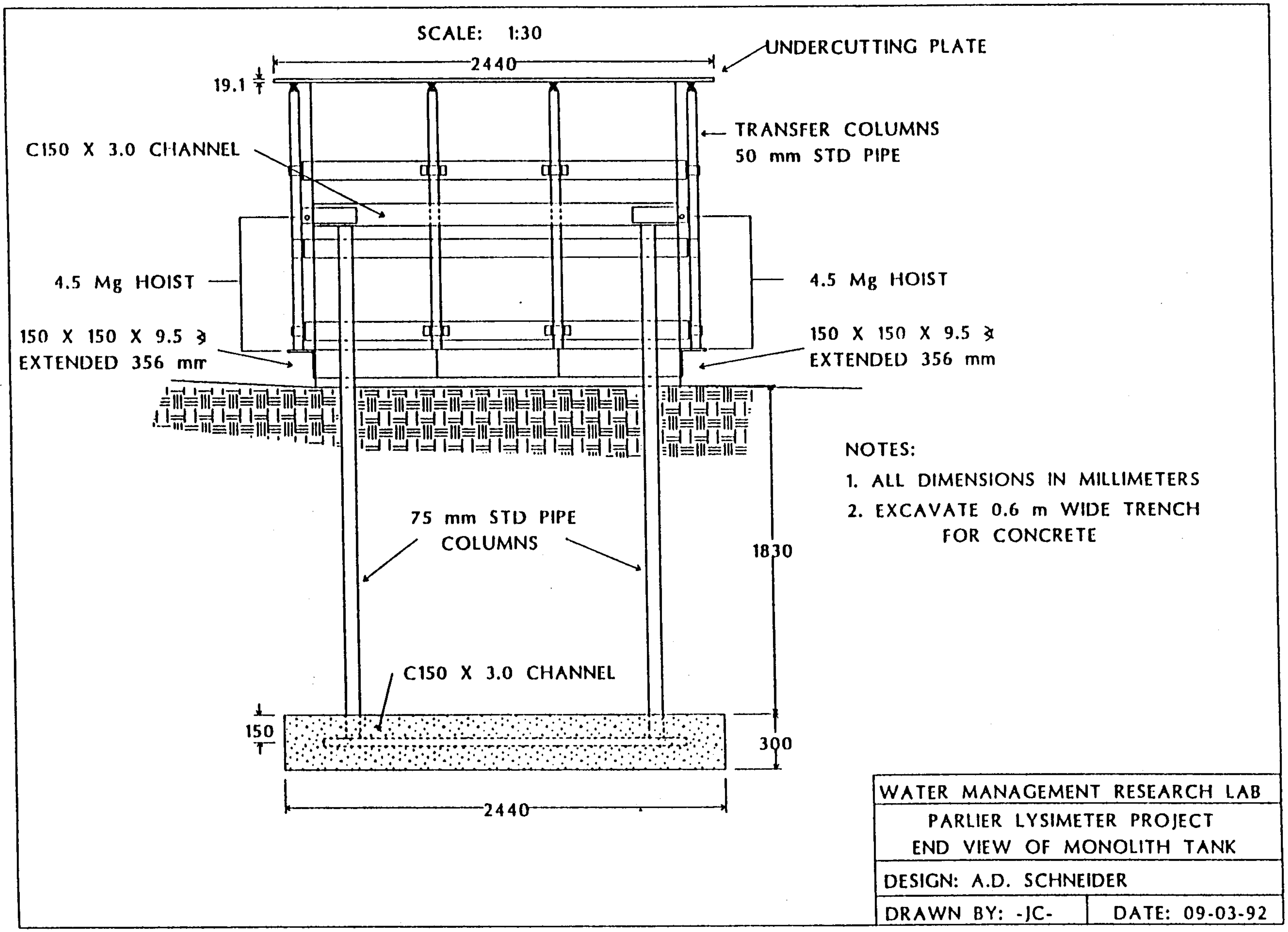

Figure 2. End view of a monolith tank with temporary attachments and the lowering frame.

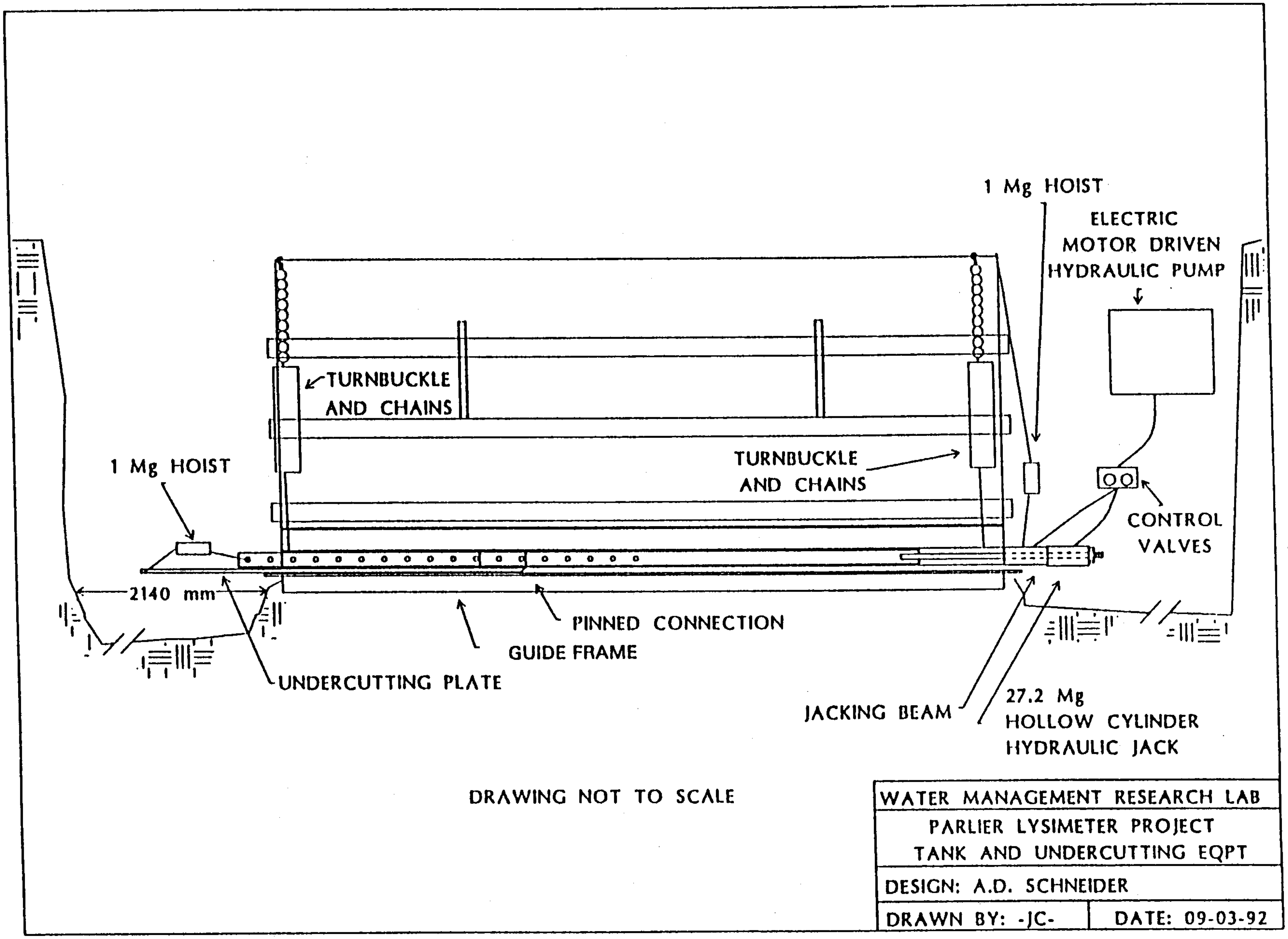

Figure 3. Side view of pressed down monolith tank and undercutting equipment.

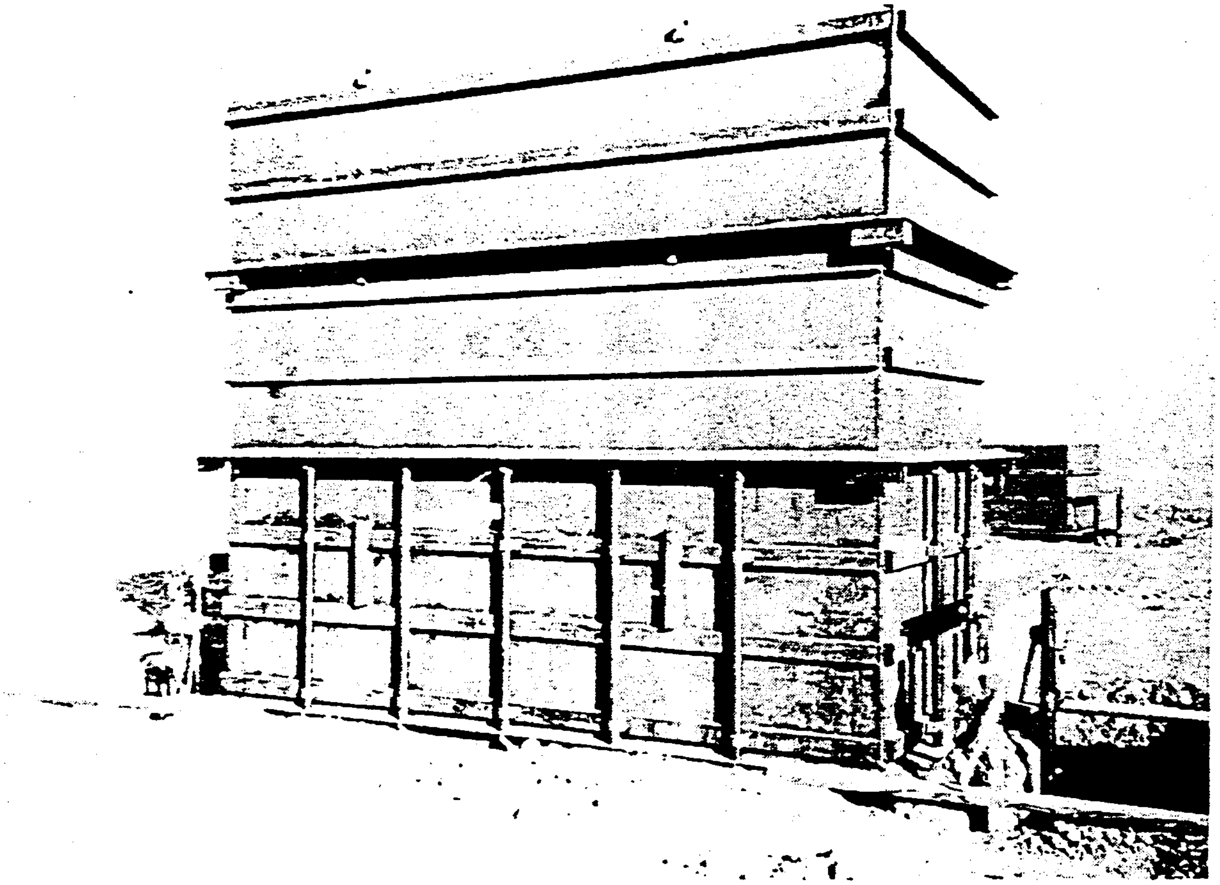

Figure 4. Monolith tank positioned to be pressed down with all equipment and deadweights in place.

Figure 5. Undercutting plated being jacked under one of the soil monoliths.

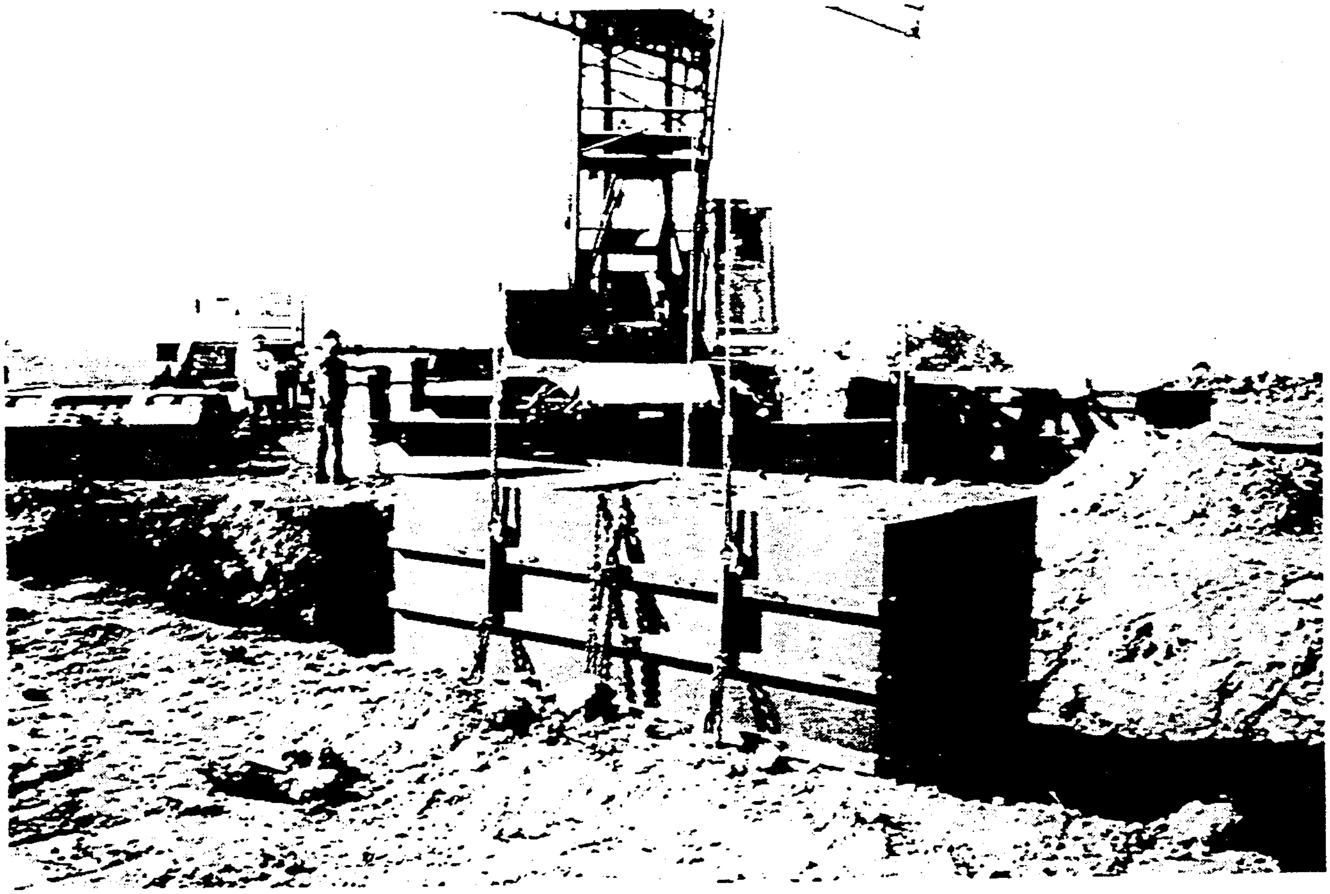

Figure 6. Soil monolith being lifted from the ground and loaded onto a truck.

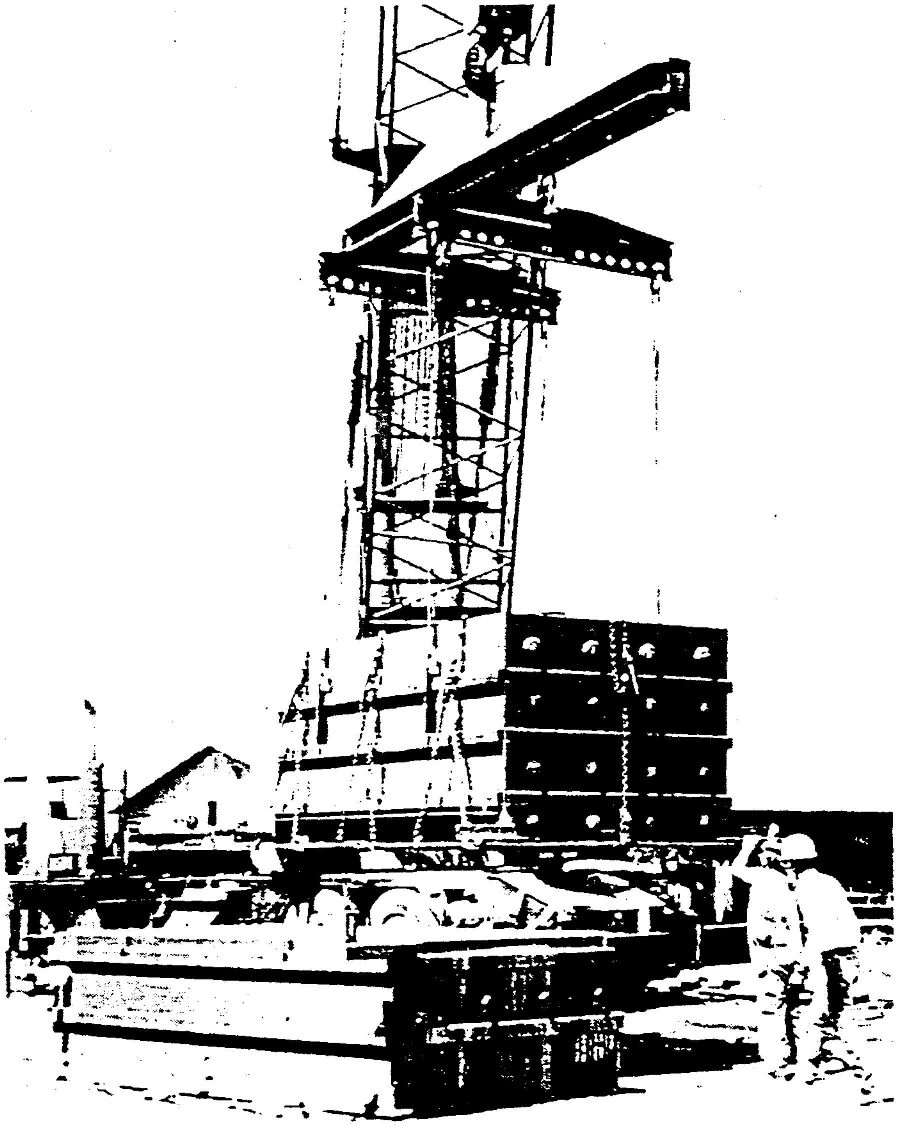

Figure 7. Monolith tank being lifted with a crane and positioned over a lower tank.